Graphical Representation of Motion

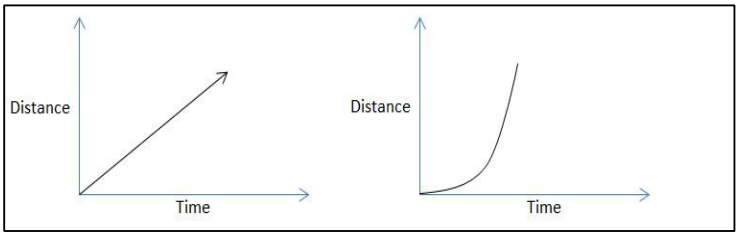
Graphs are very powerful method of presenting information. In order to describe motion of an object, we use Line Graph. Line Graphs show dependence of one physical quantity such as distance or velocity on another quantity such as time.

For graphical notation, it is convenient to take TIME along X- Axis, whereas Distance or Velocity is taken along Y- Axis.

Plotting a Graph

The following steps are needed to plot a graph:

1. Choosing the axes.
2. Choosing the scale
3. Plotting the points
4. Joining the points



Distance -Time Graph

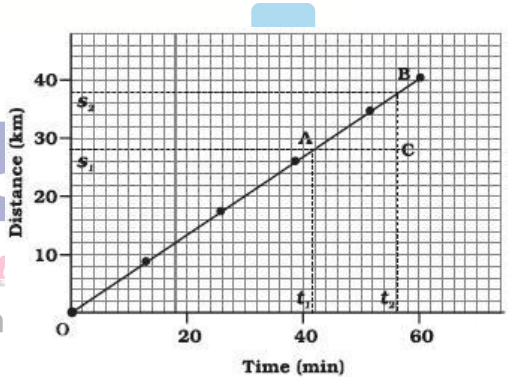
The change in the position of an object with time can be represented on the 'Distance –Time' graph adopting a convenient scale of choice.

To draw distance-time graph, time is plotted along X axis and Distance is plotted on Y axis. Distance Time graph of an object moving with uniform speed is a straight line. Conversely, distance time graph of an object is straight, the object is moving with uniform speed.

Speed from distance - time graph

Consider the object moving with uniform speed. The distance covered till time 't1' is 's1' and distance covered till time 't2' is 's2'. Thus, the object covers a distance of s2 – s1 and time interval t2 – t1. **The speed of the object is = slope of the Distance time graph**

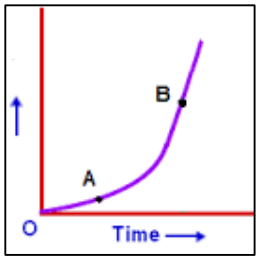
= (d2 – d1) / (t2 – t1) = BC / AC.



If the distance – time graph of an object is a straight line, the speed of the object is equal to the slope of the straight line.

The slope of a line tells how steeply it is inclined to the horizontal axis. If the line is parallel to the horizontal axis, the slope is zero.

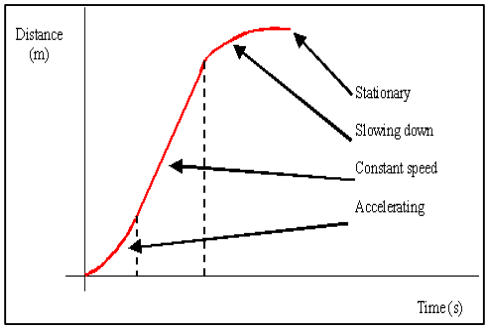
As the line gets more and more inclines to the vertical axis, its slope increases. Thus, a more steeply inclined distance-time graph indicates greater speed.



Distance -Time graph for Non uniform Motion

If an object moves with non- uniform speed, its distance –time graph is not a straight line. The inclination of the graph is different at different places, and hence, it does not have a unique slope.

When the speed of the body decreases with passage of time, then the distance – time graph will be a curve with negative slope.



LEARNING WITH INNOVATION....

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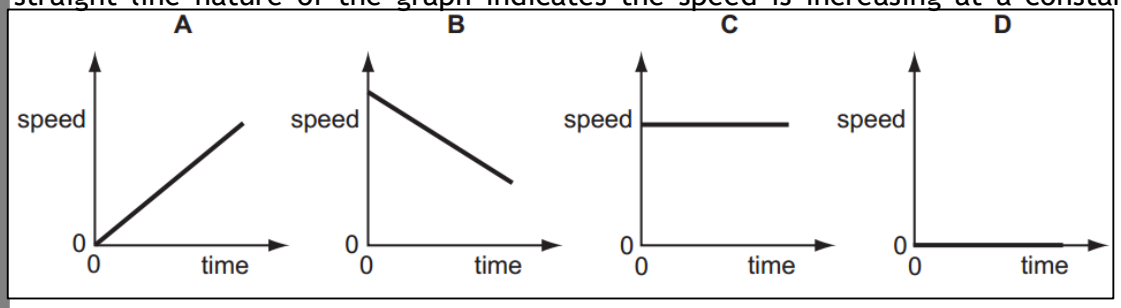
1. Accelerating
2. Constant Speed
3. Slowing down
4. Stationary

Speed - Time Graph

Look at the four speed – time graphs given below. The interpretation of:

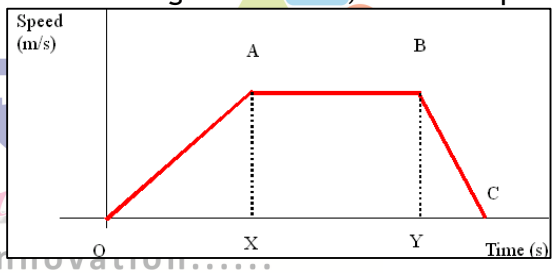
A graph: this graph shows that the speed is continuously increasing with time. The straight line nature of the graph indicates the speed is increasing at a constant rate.



B graph: this graph shows that speed is decreasing continuously as time increases. Thus it represents a decelerating object.

C graph: this graph shows that speed does not change with time, i.e. the speed remains constant. Thus, this represents an object moving with constant speed.

D graph: This graph shows that the object is at rest. As the speed remains zero as the times increases.

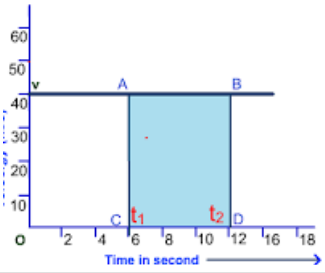


In the graph shown, there are three stages:

1. OA: speed is increasing at a constant rate.
2. AB: object moves with constant speed.
3. BC: object decelerates and comes to rest at point 'C'.

Calculate Distance from Speed Time Graph

Draw perpendicular lines to the time axis at points 'A' and 'B' corresponding to t1 and t2.The area enclosed by these perpendicular lines, the time axis and the speed – time graph is equal to the distance covered in the time interval t1 to t2.



Distance covered = area of rectangle ABCD = v (t2 – t1)

This is often called area under the curve.

Displacement - Time graph

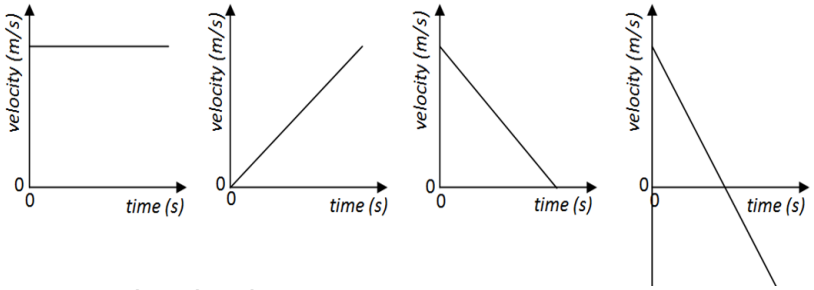
If the graph is plotted by taking displacement on the Y axis and time't' on the X axis, we get the displacement – time graph of the object.

The slope of the displacement – time graph of an object gives its velocity. There are three stages in the graph shown:

1. O sec to 5 sec: displacement increases.
2. 5 sec to 10 sec: no change in displacement.
3. 10 sec to 12.5 sec: displacement decreases as the object approaches starting point.

Velocity – Time graph

Velocity – time graph shows how the velocity of a body changes with passage of time. To draw velocity – time graph, velocity of the body is plotted along Y axis and the time taken by the body is plotted along X axis.



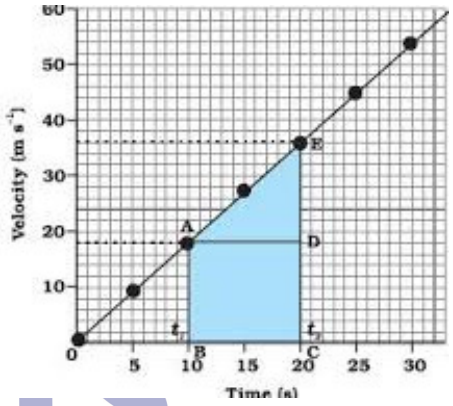
The velocity time – graph is plotted between velocity and time. Here we are actually plotting the magnitude of the velocity at different instants. There are four graphs as show. The interpretation:

A graph: the object moves with constant velocity.

B graph: the object moves with a constant acceleration

C graph: the object moves with a constant retardation

D graph: the object first moves with constant deceleration then come to rest, and moves with constant acceleration in the opposite direction.



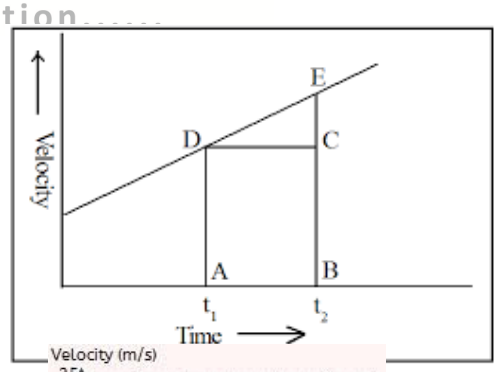
Displacement from Velocity – Time graph

From the velocity – time graph shown, the object moves with increasing velocity i.e. the object is moving with constant acceleration.

The area under the curve from time 't1' and time't2' will give the displacement.

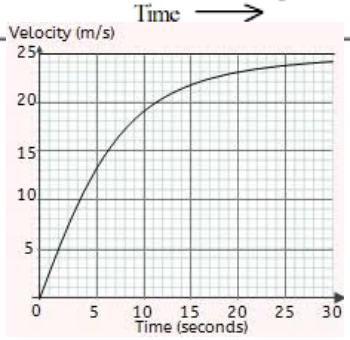
The displacement's' = area under the curve

Displacement = area of ABCE = area of triangle (ADE) + area of rectangle (ABCD)



Acceleration from Velocity – Time graph

Suppose a particle moves with a uniform acceleration of 2m/sec^2 along a straight line. This means the velocity increases by 2m/sec in every one second. In the graph shown below, the object moves with uniform acceleration.



When the acceleration is uniform, the velocity time graph is a straight line. The slope of the

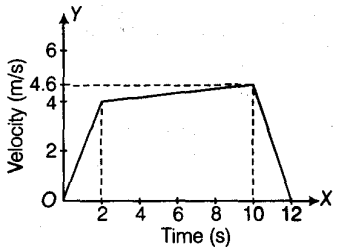
velocity time graph gives the acceleration for an object moving along a straight line.

Acceleration (a) = EC / DC

Velocity - Time Graph for non-uniform acceleration

If the acceleration of an object moving along a straight line is not constant, the velocity time graph is not a straight line.

Exercise 1



1. The velocity time graph of an ascending passenger lift is shown. What is the acceleration of the lift:
   a. During the first two seconds
   b. Between 2nd and 10th second
   c. During the last two seconds.

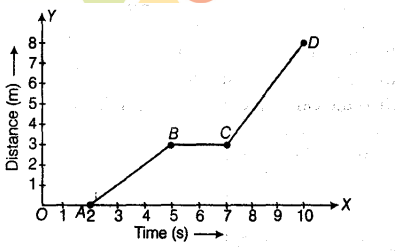
2. A body moves with a velocity of 2m/sec for 5 sec, then its velocity increases uniformly to 10m/sec in next 5 sec. Thereafter, its velocity begins to decrease at a uniform rate until it comes to rest after 5 sec.
   a. Plot a velocity time graph for the motion of the body.
   b. From the graph, find the total distance covered by the body after 2 sec and 12 sec.

3. The table gives the data about motion of a car. Plot the graph and:

Time (hr)	11:00	11:30	12:00	12:30	1:00
Distance (km)	0	20	30	65	100

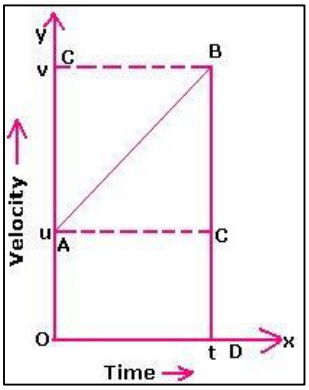
   a. Find the speed of the car between 12:00 hr and 12:30 hr.
   b. What is the average speed of the car?
   c. Is the car's motion an example of uniform motion? Justify.

4. The graph shown shows the position of a body at different times. Calculate the speed of the body as it moves from: a) A to B b) B to C and c) C to D.



Equations of motion by Graphical Method

When a body is moving along a straight line with uniform acceleration, we can establish relation between velocity of the body, acceleration of the body and the distance traveled by the body in a particular time interval by a set of equations. These equations are known as equations of motion:



1. $v = u + at$ **2. $s = ut + \frac{1}{2} at^2$** **3. $v^2 - u^2 = 2as$**

where, 'u' is initial velocity, 'v' is final velocity, 's' is distance travelled, 't' is the time taken and 'a 'is acceleration.

1. **Equation for Velocity Time Relation**: from the graph, initial velocity = OA, final velocity = BD, time interval = OD. Also, BD = BC + CD. Or BD = BC + OA.

Or BC = v - u: acceleration = BC / AC or BC/ OD and substituting OA as 't', we get: v = u + at.

2. **Equation for Position Time Relation**: from the graph, distance travelled by an object is obtained by the area under OABD under velocity time graph AB.

S = area OABD = area of rectangle OACD + area of triangle ABC
S = OA X OD + ½ (AC X BC) $s = ut + ½ at^2$

3. **Equation for Position Velocity Relation**: distance travelled is obtained from velocity time graph. S = area of trapezium OABD
= ½ (sum of parallel sides) X distance between parallel side = ½ (OA + BD) X OD
We get, s = ½ (u +v) t. Now using the first equation of motion i.e. v = u + at, we get , t = (v – u)/t. On substituting the value of t, we get $v^2 - u^2 = 2as$.

Exercise

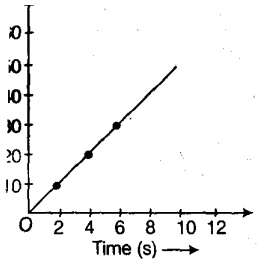
1. A train starting from rest attains a velocity of 72km/hr in 5min. Assuming that the acceleration is uniform. Find: a) the acceleration b) distance travelled by the train. [1/15 m/sec^2 and 3000m]
2. A car starts with velocity 10m/sec and accelerates at rate 5m/sec2. Find the final velocity when the car has travelled a distance 30m. [20m/sec]
3. A body is moving with a velocity of 10m/sec. If it starts accelerating with the rate of 2.5m/sec2. Find out its velocity after 10sec. [35m/sec]
4. If a car travels 50m distance in 4sec with a acceleration of 5m/sec^2, then what was its initial speed. [2.5m/sec]
5. A cyclist is moving with a speed of 14m/sec. He starts acceleration with a rate of 6m/sec2 and acquired the speed of 18m/sec. Calculate, what distance did he move in acquiring that speed? [10.67m]
6. A bus is moving with a speed 72km/hr can be stopped by brakes after atleast 10m. What will be the minimum stopping distance, if the same bus is moving at a speed of 144km/hr? [40m]

Uniform Circular Motion

If an object moves in a circular path with uniform speed, then its motion is called uniform circular motion. Since the velocity changes due to continuous change in direction and thus motion along a circular path is said to be accelerated. This acceleration is called centripetal acceleration. The direction of centripetal acceleration is towards the center of the circular path along which the body is moving. The net force acting upon such an object is directed towards the center of the circular path. This force is called centripetal force. This force helps to move the object in the circular path.

When a body takes one round of a circular path, then it travels a distance equal to its circumference which is 2πr, where r is the radius of the circular path.

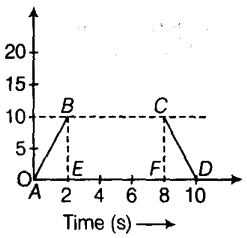
Then, speed of the body moving in a circular path, v = 2πr/t, where t is the time taken for one round of circular path and it is constant having value 22/7. Some examples:



- A piece of stone tied to a thread and rotated in a circle with a uniform speed.
- The motion of blades of an electric fan around the axle.
- The motion of the moon and the earth.
- A satellite in a circular orbit around the earth.
- A car is moving on a circular path with constant speed.

Exercise:

1. The minute hand of a wall clock is 10 cm long. Find its displacement and the distance covered from 10:00 am to 10:30 am. [34.43 cm]



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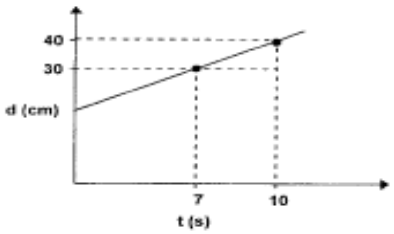
2. A train is travelling at a speed of 90 km/h. Brakes are applied, so as to produce a uniform acceleration of −0.5 m/s2 Find how far the train will go before it is brought to rest?
3. A bus starting from rest moves with a uniform acceleration of 0.1 m/s2 for 2 min. Find the speed acquired, and the distance travelled.
4. Make a velocity-time graph from the following displacement - time graph (first figure)
5. Bus retards uniformly at a rate of 3 m/s2 and stops in 10sec. With what velocity was travelling?
6. Find the displacement of a body whose velocity time graph is shown as below.(second figure)
7. A car travels $3/4^{th}$ of a circle of radius 'r'. Find the ratio of its distance covered to displacement
8. From the graph given below for the motion of a car, calculate the speed of car in interval 7s - 10s.(given here)



9. The driver of a car moving at 72 km/hr sees a buffalo in the middle of the road 100m away and hits the brakes. If he decelerates uniformly and manages to stop in 20s, did he hit the buffalo?
10. A bus starting from rest attains a velocity of 60 km/hr within 15 seconds by applying constant acceleration. Find the magnitude of acceleration so produced.
11. Rajan is driving a car with some initial velocity attains a velocity of 20 km/hr by applying constant acceleration of 1/5 ms^{-2} in 10 seconds. Find the distance covered by him in these 10 seconds.
12. A tanker starting from rest undergoes a constant acceleration of magnitude 1 ms^{-2}. If it travels for 15 seconds, calculate the distance by tanker.
13. A ball is thrown upwards with an initial velocity of 30m/s. It undergoes a constant retardation of 10 m/s^2. Calculate the maximum height attained by the ball.
14. A ball is thrown upwards with some initial velocity. It undergoes a constant retardation of 10 m/s^2 and attains a height of 50 m. Find the velocity with which the ball was thrown.
15. The front wheel of Raj's bicycle has a radius of 49 cm. It completes 66 rotations in 12 seconds. Calculate his speed.
16. Why is motion in a circle an accelerated motion?
17. What is the angle the between the direction of velocity and the acceleration in circular motion?
18. A car is moving in a circular path of radius 50m. It completes one revolution in 30 s. Calculated the speed at the end of one circle.
19. Which force helps the object to move in a circular path?
20. An object is moving in a circular path of radius 14 m. If at the end of one circle its speed is 36 km/hr, calculate the number of revolutions covered in 44 seconds.